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Satisfaction and perception of residents towards bioclimatic design strategies: Residential college buildings

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Abstract

Successful implementation of bioclimatic design strategies not only reduces energy use, but more importantly increases the resident's satisfaction. A Post Occupancy Evaluation (POE), a form of survey method was used in assessing the satisfaction and perception of residents in two residential colleges, at the University Malaya, Kuala Lumpur. Both CS-A and CS-B represent the uppermost and moderate implementation of bioclimatic design strategies. The results showed that 414 questionnaires were retrieved fully filled by occupants at CS-A while 155 respondents from CS-B returned their questionnaire. The questionnaire was based on a five-point Likert scale. Respondents were asked to rate the levels of satisfaction and perception with various aspects of the building, including the immediate environment. Detailed survey on thermal comfort had also been done by adopting the Predicted Mean Vote (PMV) Index. As initial findings, the implementations of bioclimatic design strategies at the selected residential colleges were able to provide comfort for the residents.

Introduction

Post Occupancy Evaluation (POE) is an assessment that integrates the occupant behaviour, perception and opinions of the building user after it has been operational for a certain period which enables issues to be monitored [1,2]. POE studies are necessary to verify design intentions and to analyse the impact of thermal environments on comfort and satisfaction [3], when the indoor comfort is influenced by not only architectural conditions, but also residents' psychological adaptation and behavioural adjustments [4]. The benefits that can be derived from the results of POE do not only promise to improve the quality of the indoor environment and facilities, [5] but they may also contribute to significant savings on maintenance and operation costs [6,7,8], which indirectly being a key in minimizing energy consumption while helping to bring the existing buildings towards zero-carbon targets [9]. Holistically, with an improvement in indoor environmental quality, it may contribute to not only occupant's physical health and productivity but also occupant's psychological well-being through the increased satisfaction with the overall building quality [3,10]. Thus, enhance the occupant's morale and work performance [11].

POE is widely acknowledged but rarely practiced [12]. This happens when there is a lack of agreed-upon protocols, measures and procedures which make comparisons difficult while, the acceptance, consistency and formalization of POE are inevitable [6]. This was reported by Zakaria [13] who claimed that there were no systematic collected data for various types of buildings in Malaysia. Aspects of evaluating building performance have not been emphasised widely, and the terms of POE itself is still new in Malaysia. In general, the implementation of POE is frustrated by ownership, liability, lack of knowledge and progress [14-17]. Additionally, culture is also highlighted as a barrier to the POE process when the occupants may feel that moving into a new working environment is disruptive enough and all of these inhibitors could be reduced if a pragmatic model was available [18].

There are three levels of effort in the POE process namely; indicative, investigative and diagnostic [14,15], which is based on the POE process model formulated by Preiser [7,19]. The level undertaken will depend on the availability of finance, time, manpower and the required outcome [14]. In maintaining the effectiveness and efficiency of POE, there are requirements which give results which are easy to compare with other studies, by avoiding intruding on the respondents' time and patience too much, give good value in terms of quality and content, be relevant in a given situation, be reliable and address the factors that relate to the needs, activities and goals of the people using the building.

As a part of a sustainable approach in the building environment, the development of POE should adopt a case study approach when it can provide contextual information, greater depth of qualitative data, opportunities for benchmarking performance and learning opportunities from each project for all stakeholders involved [14]. Then, it could also validate the method used as a confirmation of repeatability when a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident [20].

There are two main methods approaches in analysing comfort research through POE which are a laboratory test in a climatic chamber and field tests in buildings [21], where POE in field studies has a major influence on new understandings when historically, it was the beginning of an adaptive comfort model. In addition, it also reveals that the occupants' perceptions of the indoor environment is influenced by numerous parameters while laboratory tests still remain with many open questions regarding the definition of the key parameters for overall satisfaction within the workplace, well-being and productivity due to uncontrolled boundary conditions. In other words, the climate chamber does not represent actual conditions as in the field that is influenced by a range of complex factors.

Hassanain et al. [11] has discussed a framework for evaluating the quality of university family housing facilities which can be well adapted for other types of buildings. The framework is more organized and is diversified its investigation techniques, integrating community participation to ascertain the emerging outcomes and to define the most efficient and feasible

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interventions. Then, the new approaches have been well adapted recently when the POE was integrated with field measurement as a subjective and objective evaluation in order to assess quality of the indoor environment in a comprehensive manner [3,22-24]. With the combination of qualitative and quantitative data gathered from two types of evaluations, there are more nuanced results with a holistic picture of the investigated issues [22].

The integration of POE results in a value management process, as an essential component in the organizational learning cycle, is able to ensure that the facilities management decision-making process becomes increasingly accountable [25]. Findings of Ilesanmi [26] clearly indicate that the residents' perception of the residential environment cannot be discounted at policy, planning, design and implementation levels where satisfaction with the physical environment of residences is the most powerful predictor of resident satisfaction.

The aim of this study is to analyse the residents' satisfaction and perception of two residential colleges, which are multi-residential buildings in tropical climate region. Each residential college has the uppermost and lowest adaptation of bioclimatic design strategies particularly on day lighting and natural ventilation. Thus, the effects of the recent adoption of bioclimatic design strategies in influencing the residents' comfort level will be revealed subjectively through this POE and indirectly to understand the mutual interaction process between building and user's needs in general perspective.

Research design and approaches

Building description

The multi-residential building typically plays a role as student halls of residence, key worker accommodation, care homes and sheltered houses, typically containing catering facilities, lounges, dining rooms, health and leisure areas, offices, meeting rooms and other support areas such as laundry facilities [27]. In Malaysia, the multi-residential building, which provides accommodation for university students, is also referred to as residential college or hostel.

The background information of each residential college building acknowledged as Case Study A (CS-A) and Case Study B (CS-B) is shown in Table 1. CS-A is Dayasari Residential College Building and CS-B is Kinabalu Residential College. Both residential colleges are naturally ventilated building, which also acknowledged as free-running building [23].

Table 1. Background information on CS-A and CS-B

Characteristics	Residential colleges	
	CS-A	CS-B
Year established	1966	1985
Form of building	Low-rise	Low-rise
Building layout & arrangement	Courtyard arrangement	Linear arrangement
Orientation to sun path	N-S	N - S, NW - SE & NE - SW
Shape of the building's floor plate	Rectangle	Rectangle
Wind direction of the locality	SW	SW
Floor level (excluding GF)	3	3
Capacity / No. of residents	885	765
Total floor area (m ²)	18,212.51	11,274.23
Density (No. of residents/m ²)	0.049	0.062
Energy Efficiency Index (kWh/m ² /year)	34.52	83.96
Typical room's floor area (m ²)	16.35	14.78
Typical room volume (m ³)	45.78	47.30
Window area (m ²)	6.41	3.34
Window to wall ratio	0.66	0.38
Operable window area (m ²)	4.20	3.34
Operable window to wall ratio	0.43	0.38
Window design	Centre pivot & awning	Louver
Window location	N-S	N - S, NW - SE & NE - SW
Green area (%)	60.70	71.91

Note: N - North, E - East, S - South, W - West, NW - Northwest, NE - Northeast, SE - Southeast, SW - Southwest

CS-A which was established in 1966, is leading other residential colleges in the University of Malaya campus regarding implementation of bioclimatic designs due to the building allowing for the best utilisation of natural ventilation and day lighting [28]. The building layout that is based on a courtyard arrangement lets the transoms on top of the entrance door and wall to fully function in providing air circulation and daylight in the room. With the utilisation of daylight, it could improve the occupants' psychological health and productivity [2]. Then, the presence of wall openings creates a wind pressure inside the room. In the first place, the building's orientation to the sun's path is north-south which directly reduces the thermal effect in the room. Only the service area such as the toilet, bathroom, store, staircase and balcony are located at a west-east orientation. Regarding the enclosure and façade design, CS-A was designed with special features such as glare protection and adjustable natural ventilation options. The two types of windows, centre pivot and awning, which are tinted, offer the resident the possibility to control daylight penetration and channel the outside air/wind. As a consequence, CS-A has to be among the lowest Energy Efficiency Index (34.52 kWh/m²/year) compared to the other residential colleges which are in the range of 40 to 125 kWh/m²/year [29].

The selection of CS-B, established in 1985 as a case study, has less adaptation of bioclimatic designs particularly on day lighting and natural ventilation. This is clearly shown through the built-form configuration, orientation and site layout plan. Each residential block which is a linear arrangement has a different orientation namely, west-east, northwest-southeast and northeast-southwest. Consequently, some of the rooms will face direct sunlight from the east and west. Thus, in reducing the effect of sunlight penetration, large horizontal overhangs are located along the wall with windows as a part of the enclosure and façade design. Unfortunately, this design affects the capabilities of daylight to be fully exploited in the rooms and force the residents to switch on the artificial light even during daytime. The natural ventilation inside the room is solely depending on window openings that are facing outside, where there are no transoms above the entrance door. Thus, the comfort in the room is quite difficult to achieve without the presence of mechanical and electrical appliances. Whilst, the distribution of daylight and air circulation at the corridor area relies on an open staircase that is located at the end of the corridor. This open staircase is able to create wind pressure effects in the corridor area. Unfortunately, these special features are unable to encourage air circulation and day light penetration when the doors between staircase area and corridor are always closed for security purposes. Ventilation fans and artificial lights are needed to be switched on during daytime.

Post Occupancy Evaluation

The studies done by Khalil and Husin [30] on POE on indoor environment improvement in Malaysia's office buildings was adapted to restructure the questionnaire. The questionnaire uses a Likert Scale format where each number generally responses to a specific scale as listed below,

- -2: too dark/strongly dissatisfied/too hot/very poor/very dirty/very noisy/very uncomfortable/much decreased in comfort,
- -1: dark/dissatisfied/hot/ still air/poor/dirty/noisy/uncomfortable, decrease in comfort
- 0: neither/nor/no changes,
- +1: bright/satisfied/cold/breezy/good/clean/quiet/comfortable/increase in comfort, and
- +2: too bright/strongly satisfied/too cold/very breezy/very good/very clean/very quiet/very comfortable/ comfort much increased.

As focusing on a subjective approach in order to assess the satisfaction and perception of residents in a general perspective, the metabolic heat production is assumed as light activity (1 met) and the clothing insulation value is 0.55 clo which is a suitable value for tropical clothing [31]. The questionnaire was distributed to all residents with the minimum number of feedbacks and relying on 95% of confident level and ±5% margin of error from the overall population at

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each residential college. A simplified formula introduced by Yamane [32] was used to calculate the sample sizes,

$$n = N / 1 + N (e)^2$$

where, n is sample size, N is the population size and e is the level of precision. In this study, the level of precision is 0.05. All the collected questionnaires were analysed statistically by using a statistical software package.

Then, the percentage of responses for each scale will be multiplied by the corresponding weight which are; 2 with 5 points, 1 with 4 points, 0 with 1 point, -1 with 3 points and -2 with 2 points [33]. The sum of the products of multiplication will be divided by 100 to give the mean value. The following calibration has been adopted to quantify the degree of satisfaction for each element of performance:

- if the mean response is less than or equal to 1.49, then the respondents are "neutral, neither/nor, and no changes"
- if the mean response is between 1.50 and 2.49, then the respondents are "strongly dissatisfied, too dark, too hot, still air, very poor, very dirty, very noisy, very uncomfortable, and comfort much decreased"
- if the mean response is between 2.50 and 3.49, then the respondents are "dissatisfied, dark, hot, still air, poor, dirty, noisy, uncomfortable, and comfort decreased"
- if the mean response is between 3.50 and 4.49, then the respondents are "satisfied, bright, cold, breezy, good, clean, quiet, comfortable, and comfort increased"
- if the mean response is between 4.50 and 5.00, then the respondents are "strongly satisfied, too bright, very satisfied, too cold, very breezy, very good, very clean, very quiet, very comfortable, and comfort much increased".

Regarding thermal comfort, a detailed survey was conducted by adopting the Predicted Mean Vote (PMV) where the scale ranges from -3 to +3 where, -3: cold, -2: cool, -1: slightly cool, 0: neutral, +1: slightly warm, +2: warm, and +3: hot, whilst in relation to the Predicted Percentage of Dissatisfied (PPD), for those respondents who voted -3, -2, +2 and +3 on PMV are regarded as thermally dissatisfied [34]. The uses of the PMV and PPD in this research are quite limited when the studied buildings are naturally ventilated buildings. The PMV-PPD model have been proven only applicable for air conditioned buildings when this model ignores the important parameters including cultural, climatic, social and contextual dimensions of comfort that denies all process of thermal adaptation [35,36]. As developed by the American and European scholars, this PMV-PPD cannot be used as a generalized index for other parts of the world where the occupants would adopt different level of adaptations in different climatic zone and in different seasons of the same climatic zone [35]. In naturally ventilated buildings, the temperatures corresponding to comfortable thermal environment are keep changing due to changes indoor and outdoor environmental condition which has prompted the PMV which would always either overestimate or underestimate of the feeling of the occupants on thermal environment [35]. As consequences, the use of PMV-PPD in this subjective research would focus on the judgement of perception of residents about the indoor thermal environment in the form of thermal sensation votes base on ASHRAE 7 point sensation scale [36].

The survey was conducted in April 2011, just before the academic session 2011/2012 for the university ended and the long semester break started. Thus, the results obtained are more accurate as residents have stayed at least one semester or 14 weeks at the residential college. Then, as located in the tropical climate region, Kuala Lumpur is hot and humid all year round when it has a constant annual average of temperature and humidity [37]. Kuala Lumpur is only affected by the northeast monsoon from October to March which bringing more rainfall [38]. Therefore, there are no changes of seasons which will significantly affect the result of the survey.

Results

CS-A

A total of 414 respondents, whose replies were retrieved fully filled, represented 38.8% of male and 61.2% of female residents. The number of respondents exceeds the minimum number of feedbacks, (271 respondents relying on 95% confident level and $\pm 5\%$ margin of error from the overall population, as obtained from the sample sizes calculation). About 27% of respondents were living on the ground floor, 30% on the first floor, 23% on the second floor while 20% came from the third floor. The results of the satisfaction and perception survey from occupants at CS-A are presented in Table 2.

Table 2. Result of the satisfaction and perception survey at CS-A

		Questions	Likert Scale / Residents' responses (%)					Mean	Overall Rating
			-2	-1	0	+1	+2		
Visual Comfort	1	In your own perception, please rate the natural day lighting in this room.	16.7	20.5	22.9	26.9	13.0	2.90	Dark
	2	In your own perception, please rate the artificial day lighting in this room.	8.9	18.8	28.3	29.0	15.0	2.94	Dark
	3	Overall, how satisfied are you with the quality of lightings in this room?	8.7	17.0	31.3	26.5	16.5	2.88	Dissatisfied
Thermal Comfort	4	How do you feel about thermal comfort in this room?	12.8	17.0	26.6	26.2	17.4	2.95	Hot
Air Movement	5	Without the aid of mechanical fans; just by opening the windows or/and doors, please rate the air movement of your room.	18.4	20.4	21.9	23.8	15.5	2.93	Inconspicuous still air
	6	What is your rate for the overall quality of indoor ventilation in this room?	14.8	16.4	26.4	27.1	15.3	2.90	Poor
	7	How satisfied are you with the provision of air movement in this room (e.g. opening)	13.3	16.5	24.0	30.6	15.5	3.00	Dissatisfied
Cleanliness	8	What is your perception with the level of cleanliness in this room?	12.2	13.4	22.4	33.2	18.8	3.14	Dirty
Noise pollution	9	How do you feel with the noise or vibration? (e.g. From traffic, mechanical systems)	13.5	15.5	25.6	27.0	18.4	2.99	Noise
	10	What is your rate for the overall quality of noise control in this room?	14.3	12.9	25.7	28.9	18.2	3.00	Poor
Overall comfort	11	What is your overall comfort level in your room?	14.5	11.6	21.2	33.6	19.1	3.15	Uncomfortable
	12	Do the overall room conditions affect the degree of your work productivity?	14.8	11.6	20.3	32.7	20.6	3.19	Decreased

Referring to this survey, the majority of the respondents were at a comfort level in all aspects especially air movement (breezy: 23.8%, good quality of indoor ventilation: 27.1%, satisfied with the provision of air movement: 30.6%), and overall comfort (comfortable: 33.6%). Moreover, most of the respondents indicated that their work productivity has been increased (32.7%) due to being comfortable (33.6%). Regarding visual comfort and the overall perception of respondents towards quality of lightings in the room was neutral (31.3%) even though the majority of the respondents were satisfied with both natural day lighting (bright: 26.9%) and artificial lighting (bright: 29%). The same result was also obtained on the subject of thermal comfort where most of the respondents were feeling neutral (26.6%) with the level of thermal comfort. By adopting the degree of satisfaction, where each criterion of performance was based

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on a gradual scale, the overall rate of respondents' satisfaction was in the range of uncomfortable level when the mean response was between 2.50 and 3.49 as presented in the last two columns in Table 2. Throughout the detailed survey on thermal comfort, the majority of the respondents, representing 48.1% were feeling neutral while 16.5% of respondents voted -3, -2, +2 and +3 on PMV were regarded as thermally dissatisfied (Table 3).

Table 3. Predicted Mean Vote (PMV) at CS-A

Question	Room location according to the floor	Predicted Mean Vote / Residents' responses (%)						
		-3	-2	-1	0	+1	+2	+3
		Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot
Overall, how do you feel about thermal comfort in this room?	Ground floor	0	0	9.5	57.1	19.8	9.5	4.8
	First floor	0	4.3	4.3	51.1	23.4	14.9	2.1
	Second floor	2.9	5.7	8.6	42.9	28.6	8.6	2.9
	Third floor	0	3.1	0	43.8	40.6	6.3	6.3
	Overall	0.8	2.5	10.7	48.1	25.5	9.9	2.5

According to the room location, most of the respondents who are regarded as thermally dissatisfied are staying at the top of the building and heat is the prominent issues.

The majority of the respondents who stayed on the ground floor were feeling neutral with 57.1% of residents' responses and the percentage of those who rated slightly warm become higher with the increasing floor level of the building.

Statistically, there are no significant differences between gender and indoor environment conditions which include visual comfort, thermal comfort, air movement and overall comfort in living units/rooms at CS-A ($p > 0.05$). Thus, the gender and room location factors did not influence the residents' sensation towards indoor environmental conditions. Nevertheless, a higher mean was obtained with male respondents when in natural day lighting, with adequate air movement provision, better air quality with sufficient indoor ventilation, to enhance overall comfort and degree of work productivity as compared to the response given by the females. Vice versa, a higher mean was obtained with female respondents who regarded artificial lighting, quality of lighting and thermal comfort as important. Furthermore, there are significant differences between the gender, $F(df = 1,362, p < 0.05) = 4.528$; and the PMV Index for thermal comfort indicated that the males showed a higher mean, illustrating the influences of this factor. The Pearson correlation was used to correlate between each criteria and overall comfort, as well as work productivity with regard to the residents' satisfaction and perception (Table 4).

Table 4. Correlation of residents' satisfaction and perception between overall comfort, work productivity and indoor environment criteria at CS-A

		Natural daylighting	Artificial lighting	Overall lighting	Thermal comfort	Air movement	Indoor ventilation	Air movement	Cleanliness	Noise level	Noise control	PMV
Overall comfort	Pearson correlation	0.243**	0.219**	0.205**	0.172**	0.125*	0.289**	0.356**	0.584**	0.757**	0.890**	0.064
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.225
Work productivity	Pearson correlation	0.203**	0.203**	0.190**	0.167**	0.124*	0.256**	0.317**	0.545**	0.729**	0.862**	0.065
	Sig. (2-tailed)	0.000	0.000	0.000	0.001	0.012	0.000	0.000	0.000	0.000	0.000	0.217

* correlation is significant at the 0.05 level (2-tailed), ** correlation is significant at the 0.01 level (2-tailed)

There are significant positive relationship of satisfaction and perception levels with all criteria especially cleanliness, noise level and control which showed a strong relationship for both overall comfort and work productivity. Thus, these three criteria would be more influential in the overall comfort and degree of resident's work productivity.

CS-B

The number of respondents only exceeded the minimum of feedbacks, relying on 83% of confident level and $\pm 5\%$ margin of error from the overall population. A total of 155 respondents filled in the questionnaires fully filled representing 39.0% of male and 61.0% of female residents. About 23.4% of respondents live on the ground floor, 31.2% on the first floor, and 33.1% on the second floor while 12.3% came from the third floor. The results of the satisfaction survey from occupants at CS-B are presented in Table 5.

Table 5. Result of satisfaction and perception survey at CS-B

		Questions	Likert Scale / Residents' responses (%)					Mean	Overall Rating
			-2	-1	0	+1	+2		
Visual Comfort	1	In your own perception, please rate the natural day lighting in this room.	0.6	12.3	32.3	45.1	9.7	2.99	Dark
	2	In your own perception, please rate the artificial day lighting in this room.	0.0	5.8	25.3	49.4	19.5	3.38	Dark
	3	Overall, how satisfied are you with the quality of lightings in this room?	0.0	3.9	30.1	47.0	19.0	3.25	Dissatisfied
Thermal Comfort	4	How do you feel about thermal comfort in this room?	6.6	16.6	31.8	37.1	7.9	2.83	Hot
Air Movement	5	Without the aid of mechanical fans; just by opening the windows or/and doors, please rate the air movement of your room.	25.2	31.0	28.4	13.5	1.9	2.35	Still air
	6	What is your rate for the overall quality of indoor ventilation in this room?	2.6	20.0	41.9	32.3	3.2	2.52	Poor
	7	How satisfied are you with the provision of air movement in this room (e.g. opening)	1.9	18.2	48.1	27.3	4.5	2.38	Strongly dissatisfied
Cleanliness	8	What is your perception with the level of cleanliness in this room?	0.6	9.1	38.3	43.5	7.8	2.96	Dirty
Noise pollution	9	How do you feel with the noise or vibration? (e.g. From traffic, mechanical systems)	1.3	9.1	38.3	43.5	7.8	2.81	Noise
	10	What is your rate for the overall quality of noise control in this room?	0.0	9.8	35.9	45.8	8.5	2.91	Poor
Overall comfort	11	What is your overall comfort level in your room?	2.6	3.2	38.1	44.5	11.6	2.89	Uncomfortable
	12	Do the overall room conditions affect the degree of your work productivity?	1.3	5.2	32.2	41.9	19.4	3.15	Decreased

The majority of the respondents in CS-B were in a comfort level in all aspects especially visual comfort (bright, natural and artificial lighting: 45.1% and 49.45%), thermal comfort (cold: 37.1%), cleanliness (47.7%: clean), noise pollution (quiet: 43.5%, good quality of noise control: 45.8%) and overall comfort (44.5%: comfortable). Additionally, most of the respondents pointed out that their work productivity has been increased (41.9%) due to having comfortable (44.5%) room conditions. Only one aspect was not fulfilled, namely, air movement where the majority of respondents rated the air movement in their rooms as "still air" (31.0%). Subsequently, 41.9% and 48.1% of respondents stated neither/nor for overall quality of indoor ventilation and the poor air movement in their rooms. As a consequence, the overall rating of respondents' satisfaction, particularly on the air movement in the room and provision of air movement were in the range of "very uncomfortable", where the mean response was between 1.50 and 2.49.

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Simultaneously, other aspects namely visual comfort, thermal comfort, cleanliness, noise pollution and overall comfort, showed the same overall rating by occupants in CS-B as in CS-A.

The detail survey on thermal comfort showed the majority of the respondents, (representing 33.8%) feel neutral while 31.1% of respondents who voted -3, -2, +2 and +3 on the PMV are regarded as thermally dissatisfied (Table 6).

Table 6. Predicted Mean Vote (PMV) at CS-B

Question	Room location according to the floor	Predicted Mean Vote / Residents' responses (%)						
		-3	-2	-1	0	+1	+2	+3
		Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot
Overall, how do you feel about thermal comfort in this room?	Ground floor	0	0	5.6	33.3	33.3	22.2	5.6
	First floor	0	2.2	10.9	52.2	17.4	13.0	4.3
	Second floor	0	2.0	10.2	24.5	34.7	18.4	10.2
	Third floor	5.3	0	0	10.5	21.1	57.9	5.3
	Overall	0.7	1.3	7.9	33.8	27.2	22.5	6.6

As already explained on issues related to CS-A, the heat would be a prominent issue at CS-B when the percentage of respondents who rated: slightly warm, warm and hot on each floor were quite high. The majority of the respondents who stayed on the ground and second floor felt that their indoor environment was slightly warm; these were 33.3% and 34.7% of residents' responses respectively. While for those who stayed on the top floor, 57.9% of residents' rated their indoor environment as warm.

Statistically, there are no significant differences between gender and room location ($p > 0.05$). Therefore, the gender and room location factors did not influence the residents' sensation towards the indoor environmental conditions. Additionally, a higher mean shown by the male respondents indicated the air movement provision was important, while other factors were reported to be important by female respondents. This contradicts with the situation at CS-A, where there were no significant differences between gender $F(df = 1, 148, p > 0.05) = 2.285$ and PMV Index. The Pearson correlation was used to correlate between each criteria and overall comfort, as well as work productivity with regard to the residents' satisfaction and perception (Table 7).

Table 7. Correlation of residents' satisfaction and perception between overall comfort, work productivity and indoor environment criteria at CS-B

		Natural daylighting	Artificial lighting	Overall lighting	Thermal comfort	Air movement	Indoor ventilation	Air movement	Cleanliness	Noise level	Noise control	PMV
Overall comfort	Pearson correlation	0.410**	0.376**	0.433**	0.591**	0.386*	0.601**	0.533**	0.458**	0.467**	0.461**	-
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.216**
Work productivity	Pearson correlation	0.220**	0.290**	0.192*	0.370**	0.127*	0.307**	0.302**	0.414**	0.296**	0.303**	0.069
	Sig. (2-tailed)	0.006	0.000	0.017	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.403

* correlation is significant at the 0.05 level (2-tailed), ** correlation is significant at the 0.01 level (2-tailed)

Overall, there are significant positive relationship of satisfaction and perception levels with all criteria except PMV which showed a negative relationship with the overall comfort. Only indoor ventilation and air movement showed a strong relationship with the overall comfort. As consequences, these two criteria are more influential in the overall comfort and the degree of resident's work productivity at CS-B.

Discussion

By comparing the residents' responses of both case studies, CS-A is in the range of comfort for most of the indoor environmental aspects, except for overall quality of lighting and thermal comfort. For these two aspects, the majority of the respondents voted neither/nor.

Overall, the percentages of each aspect given by the respondents of CS-A were lower compared to those given by the respondents of CS-B even within the same scale of rating. Indirectly, it showed that there are lots of improvements needed to fulfil the majority of the residents' level of satisfaction although a large number of bioclimatic design strategies were recently implemented. This is supported by the degree of satisfaction, for the criterion of performance which resulted in the range of being uncomfortable. The visual comfort should be given more consideration and this aspect showed the lowest mean value, 2.88.

Although at CS-B, there was a less adaptation of bioclimatic design strategies particularly on daylighting and natural ventilation as compared to CS-A, most of the residents at CS-B were still satisfied with most of the indoor environmental aspects. Higher percentages of residents' responses, which exceed 40%, were shown in the comfortable range. Moreover, a higher mean value was also shown for visual comfort particularly for artificial lighting which indirectly showed the efficiency of artificial lighting which was acceptable compared to day lighting in providing satisfactory visual comfort to residents. As a consequence, it is hypothesized that a higher Energy Efficiency Index (EEI) at CS-B (Table 1) was driven by greater use of artificial lighting. This differs with the respondents at CS-A, where the mean values of artificial and day lighting is equal. The internal courtyard arrangement of building layout has optimised the daylight usage [39,40] especially in the corridor and staircase area. Whilst, the tinted windows offer the resident the possibility to control daylight penetration and reduce annoyance glare even though the window to wall ratio is quite big, 0.66 with 6.41m² of window area. Thus, contributing to lessening the electricity usage for artificial lighting. However, with CS-B, the linear arrangement of building layout forces the residents to continuously switch on the electric light at the corridor area even during the day.

Higher percentages of residents' response at CS-B; exceeding 40% as compared to CS-A, can be explained by scrutinising the total number of respondents. In CS-A the minimum number of respondents relying on 95% of confident level with $\pm 5\%$ margin of error from the overall population, whereas the minimum number of feedbacks at CS-B was only 83% of confident level with $\pm 5\%$ margin of error. The percentage of residents response at CS-B became more directed to a specific scale while CS-A was more scattered. This has contributed to the research limitation.

Air movement was the only issue at CS-B which was clearly identified by the degree of satisfaction of the respondents. The majority of respondents rated inconspicuous still air for the air movement, fair for overall quality of indoor ventilation and neither/nor with the provision of air movement in the room. This was probably due to the smaller operable window to wall ratio with the louver window design which has limited the control of air movement in the rooms by the residents. There was also the single-sided ventilation which has led to the residents to be highly dependent on the ceiling fan to improve the air circulation inside the room. In contrast to the situation at CS-A, where the majority of residents rated breezy for the air movement, with good quality of indoor ventilation and satisfaction with the provision of air movement in the room. The two types of windows namely, centre pivot and awning, have provided the residents the mechanism to channel the outside wind into the room even though the position of the windows and the building orientation are not in accordance with the wind flow direction of outside air [29]. The awning windows are located above the centre pivot could directly play a role as a high level exhaust opening. Moreover, the presence of wall openings and transom on top of the entrance door and wall could create a wind pressure inside the room [39]. Indirectly, enhance the air circulation and the effectiveness of ventilation by cross-flow ventilation system [41].

Then, the cleanliness and noise pollution are the two aspects that need a greater attention at CS-A to improve the quality of building environment in pursuing a better quality of life. The

majority of respondent claimed, the level of cleanliness and noise pollution are clean and quiet respectively with a good quality of noise control in the room. Nevertheless, the percentage of respondents who voted negative scale for both environmental aspects were higher in CS-A than CS-B. As a consequence, the overall comfort and work productivity were affected and indirectly denied the effectiveness of bioclimatic design strategies which were well adapted at CS-A.

A further survey on thermal comfort revealed a higher adaptation of bioclimatic designs of CS-A, that allow for the best utilisation of natural ventilation and day lighting thus enabling the residents to feel comfortable within their living environments. Only 16.5% respondents in CS-A indicated that they were thermally dissatisfied compared to those in CS-B, where the percentage was almost two times higher, at 31.1% as shown in Figure 1.

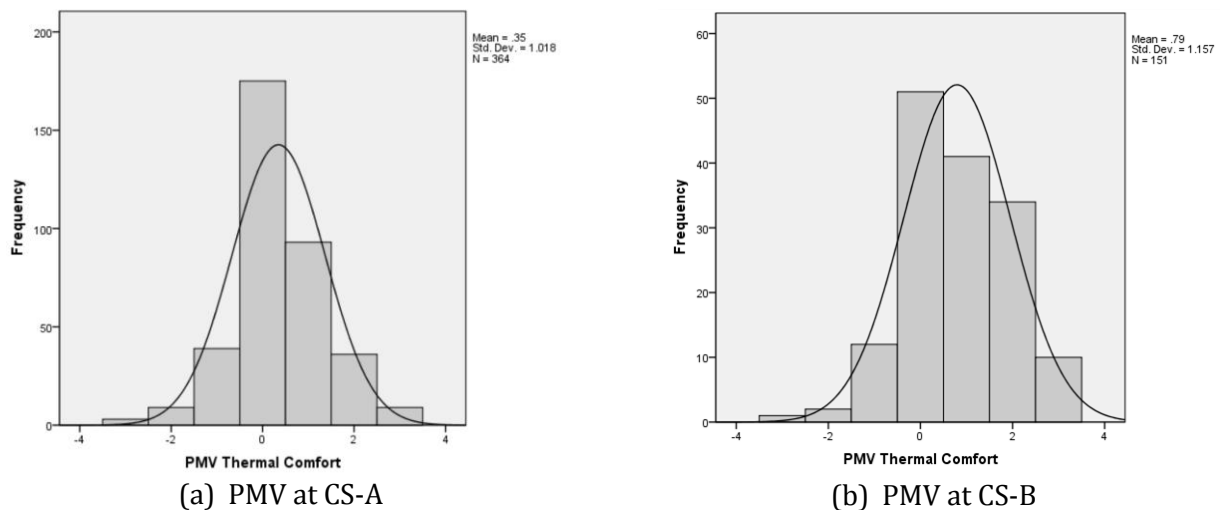


Fig. 1. Predicted Mean Vote (PMV) at CS-A (a) and CS-B (b)

Comparatively, the indoor environment of CS-B was hotter than CS-A. The percentage of respondents at CS-B who rated their indoor environment as hot were higher than at CS-A. This shows the effectiveness of the bioclimatic design particularly in the provision of natural ventilation to deliver a comfortable indoor environment for the residents.

According to the room location, most of the respondents who were thermally dissatisfied live on the top floor of the building. There were a higher percentage of response from the residence, indicating, "slightly warm", "warm" and "hot" than elsewhere. This situation happened at both residential colleges where these were designed with a flat concrete rooftop. Comparative study conducted by Tang et al. [42] showed non air-conditioned buildings with vaulted roof can have lower indoor temperatures as compared to a flat roof where the vaulted roof would dissipate more heat by convection and thermal radiation at night due to the enlarged curved surfaces. According to Davis et al. [43], higher temperatures were recorded at the top level of flats and apartments compare to ground floor. Approximately, more than 40% of solar gain by a typical five storey flat in the tropical climate region is through its roof [44]. As a roof covering material, the performance of cement is marginally worse than clay tiles [45].

Thus, green roof that also known as a rooftop garden with the combination of vernacular architecture, could be an ideal alternative and which has been proven to provide a significant reduction in the peak heat transfer to lowering of indoor air temperature as well as improving the outdoor environment in terms of carbon uptake [46-48]. A well-designed passive cooling systems that can reduce heat absorption and heat conduction of cement-based roofs by using an appropriate reflector and insulator would be most needed in the tropic environment of Malaysia [49].

Referring to Table 6, the majority of the respondents at CS-B who live on the ground floor also claimed the heat was an important issue, where most of the rooms are adjacent to the

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sports court. The sports court is made from concrete paving and therefore would store heat, exceeding 50% of radiation and would remain hot longer than unpaved or grass surfaces which only stored 5% of heat [50,51]. Thus, more tree with large canopy should be planted between the residential buildings and sports court when the air temperatures over grass surfaces are - 12.2°C to -10°C cooler than over exposed soil, while under a tree at midday are often -5°C lower than in comparable unshaded areas [52].

Conclusions

The implementation of bioclimatic design strategies, particularly on day lighting and natural ventilation at residential college buildings in the tropical climate region has a significant impact on the satisfaction level of the residents in a positive manner. Although the majority of the respondents were in a comfort level; including thermal comfort and indoor air quality, visual comfort, acoustic comfort, cleanliness and overall comfort, there is still room for improvement where the degree of satisfaction, which was based on a graduated scale, was shown otherwise.

Through this POE studies, it was revealed that the majority of residents are satisfied with the internal courtyard arrangement of the building layout which optimises the daylight usage especially in the corridor and staircase area. The position of a transom on top of the entrance door and wall has functioned in providing daylight and air circulation inside the room. Two types of windows namely, centre pivot and awning, has given the residents a control of their natural ventilation. The tinted glass windows have offered the resident the possibility to control daylight penetration and reduce annoyance glare even though the window to wall ratio is quite big, 0.66 with 6.41m² of window area.

Linear arrangement of building layout has limited the utilisation of daylighting and natural ventilation in the room, which has indirectly affected the satisfaction level of residents and efforts to reduce electricity consumption. The failure of daylight to reach at the corridor area has caused the residents to switch on the electric light even during the day and would require exhaust fans to promote air circulation. As consequences, critical studies on visual comfort, thermal comfort and indoor air quality including room openings for the provision of air movement should be carried out in buildings with a linear arrangement and with various orientations.

Placing a sports court without a well planned and good maintenance of landscape between the residential buildings would deem inappropriate as this would increase the surrounding temperatures. To reduce the indoor air temperature especially on the top level of residential buildings with flat roof, the rooftop garden should be well implemented.

In order to have an accurate result of satisfaction and perception survey, it is necessary to have a greater number of respondents which exceeding the minimum number of feedbacks with a 95% of confident level and $\pm 5\%$ margin of error to represent the overall population. Additionally, the scope of the study should include subjective and objective evaluation by which the combination of these methods would give a more comprehensive result for the investigated issues. Lastly, it should be borne in mind that in optimizing the day light utilisation and natural ventilation in low energy buildings, the comfort of the residents should not be sacrificed.

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